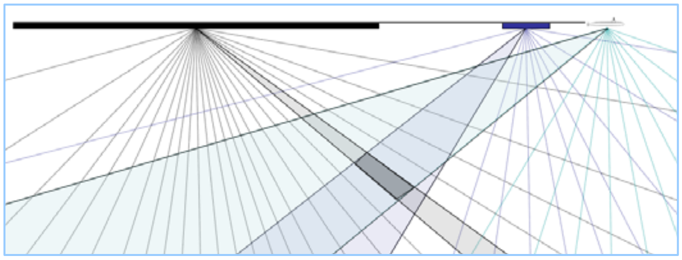
CEROS - National Defense Center of Excellence for Research in Ocean Sciences

CEROS Project Description

Project: **Doppler-Compensated Interarray Broadband Cross-Correlation (DIBX) for Sonar Contact Geo-localization** [1]

Contractor: **Lockheed Martin ORINCON, Honolulu HI**



Summary: Modern ASW operations often occur in contact-rich environments where it is difficult to establish and maintain tactical control in the near-ship environment. The contact management challenges in such high traffic environments often overwhelm sonar operators and can negatively impact the mission. Furthermore, these environments severely constrain a ship's ability to maneuver, limiting the efficacy and practicality of Target Motion Analysis (TMA) techniques. This project addresses the issue of sonar workforce overload by applying acoustic correlation processing to automatically detect and geo-localize sonar contacts, from loud commercial vessels to quiet threat submarines. The developed system provides automation to a high-priority ASW sensor, makes valuable additions to current detection and localization capabilities, and aids submarine tactical control and security.

Description: Correlation processing for geo-localization has an extensive history with submarine sonar and fire-control systems. The U.S. Navy first utilized this type of processing in the early sixties. More recently, as a joint effort between Submarine Pacific (SUBPAC) N7 and the Naval Underwater Warfare Center (NUWC), an AN/WLY-1 hydrophone array was mounted topside of a Los Angeles class submarine to improve the Navy's geo-localization capabilities. Nonetheless, these efforts were abandoned because of high production costs and/or the poor signal-to-noise ratio (SNR) yielded by the experimental systems.

Current methods of contact geo-localization require multiple course changes to evaluate bearing aberrations in determining a contact's course, speed, and range. These time consuming and labor intensive methods are a key weakness of modern combat systems as demonstrated in numerous cooperative exercises against quiet diesel targets. DIBX solves this problem by integrating proven and novel algorithms with existing submarine arrays. DIBX is a low cost solution because it employs existing sonar arrays, rather than developing new hardware.

Broadband acoustic energy is produced by all ships and submarines and is the most common signal available for passive acoustic processing. The observed intensity levels of these signals vary with contact platform type and its operating posture, range, and aspect to the sensors. Furthermore, as a target nears a sensor field, its relative velocity can vary in relation to each

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[1] CEROS FY04 contract 53644, initiated 1 July 2005.

sensor. For example, a target may be opening in range from one sensor while closing to another. If not corrected, Doppler effects induced by differences in relative motion will render the target “invisible” to standard correlation processing detection. DIBX overcomes these challenges associated with correlation-based detection of close-aboard targets by searching across an ensemble of Doppler-compensated time-series signals. This algorithm is the crucial element in allowing for correlation across large baseline arrays (i.e., Arrays B and C).

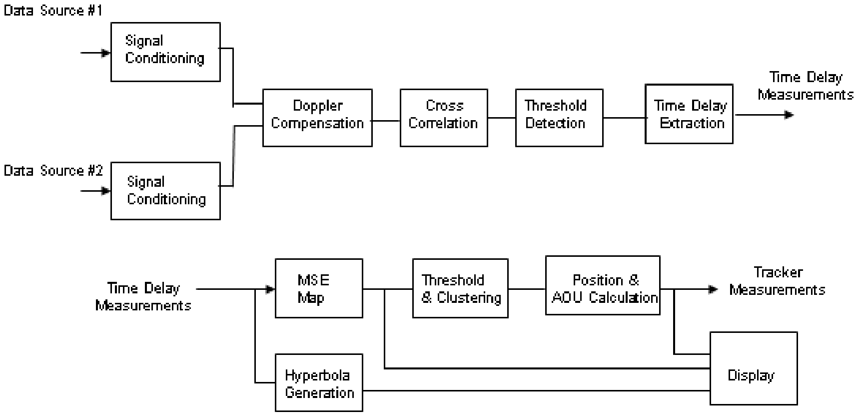

Figure 1. DIBX system design.

An overview of the DIBX system is shown in Figure 1. Signal conditioning is performed on the input time-series data of three element-level pairs to increase SNR. Doppler compensation is then applied to accommodate any decorrelation between two receivers. The conditioned and Doppler-compensated signals are cross correlated by means of a smooth coherent transform (SCOT) to determine the relative time delay-of-arrival (TDOA) or lag of a contact signal arriving at the sensor pairs. A detection threshold is set based on the time-bandwidth product and the desired probability of false alarm. The effects caused by noise and source interference are reduced by clustering each scan on the Doppler ratio/time-lag plot where the time delays are extracted through a centroid computation. TDOA values from the three element pairs are processed to triangulate the possible geo-location points of the source on a local grid. A mean-squared error (MSE) matrix is formed for a grid of points representing the area of interest in the receiver vicinity. Low MSE values are then clustered yielding a map of spatial regions containing the source. The location and extent of these regions are analyzed to produce a position and an area of uncertainty (AOU) ellipse. These measurements are further processed by the Object-oriented Multi-Hypothesis Tracker (OMHT) where the resulting track information can be delivered to submarine sonar and fire-control systems.

The range/bearing measurements are depicted on a simplified geo-display for visual validation and verification, as shown in Figure 2. This display color-codes own-ship position in purple, position estimates in green, and varying colors for each unique contact track (i.e., red). The lower part of the display shows correlograms of the three element-level sensor pairs.

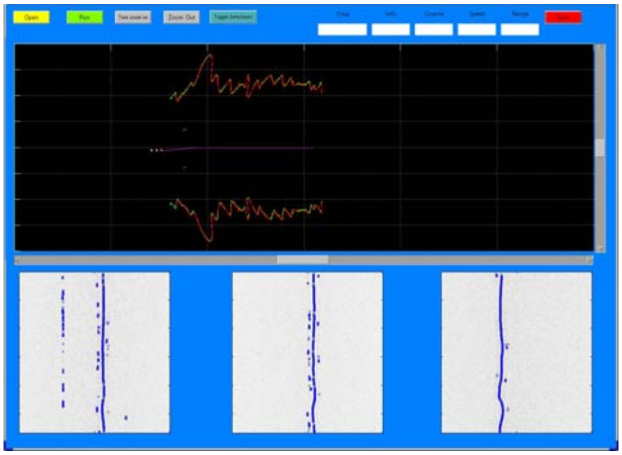

Figure 2. Prototype geo-display example, with measurement and track information on the upper panel, and correlograms on the lower panels.